Organism Pest Risk Analysis:
Risks to the Conterminous United States Associated with the Woodwasp, *Sirex noctilio* Fabricius, and the Symbiotic Fungus, *Amylostereum areolatum* (Fries: Fries) Boidin.

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Executive Summary

This pest risk analysis (PRA), was conducted at the request of the United State Department of Agriculture (USDA), Animal Plant Health Inspection Service (APHIS), Plant Protection and Quarantine (PPQ), Emergency and Domestic Programs (EDP) unit, to examine the risks associated with the woodwasp, *Sirex noctilio* Fabricius, and the symbiotic fungus, *Amylostereum areolatum* (Fries: Fries) Boidin.

This risk analysis evaluates the overall risk *S. noctilio* and *A. areolatum* pose to the United States using an APHIS-PPQ organism pest risk assessment template. Because of the obligate relationship between *S. noctilio* and *A. areolatum*, the organisms were analyzed together, with regard to potential risk; however, *S. noctilio* is the primary focus.

Sirex noctilio scored High with regard to Cumulative Risk, Habitat Suitability, Dispersal Potential and Economic Impact. Its Environmental Impact was Medium for the United States, based on the wasp's potential to impact the endangered *Pinus radiata*, and introduction of a non-native nematode species, *Beddingia siricidicola*, for use as a biological control agent on *S. noctilio*. *Sirex noctilio* scored Low with regard to Host Range because it prefers species in the genus *Pinus*. These scores indicate that *S. noctilio* could pose a serious potential economic threat to the U.S. forestry industry.

Climate will most likely not limit the distribution of *S. noctilio* in the United States. Consequently, its projected area of U.S. colonization will depend on the distribution of pines. Pines are found throughout the United States, with the highest concentrations in the south, west, northeast, and north central states, respectively.

The Southern United States has a concentrated and uniform distribution of pine forests, while those in the West, North Central and Northeast are more dispersed. *Pinus taeda* L. is the major planted pine species in the South; this species is a suitable host plant for *S. noctilio*. The estimated annual value of southern softwood logs, pulpwood, timber and veneer is greater than $8 billion. By using the U.S. Forest Service regional breakdown, the South is the world's largest softwood timber producer, and its output is projected to increase. Moreover, the South's tendency to encounter tropical storms and hurricanes has left many forests damaged, producing host material for *S. noctilio*. With southern pine resources affected by these storms, the economic vitality of this commodity is at risk, as is the tendency for *S. noctilio* introduction is increased.

However, there is uncertainty regarding the rate at which spread will be accomplished, and the degree of impact that *S. noctilio* will have on U.S. pines resources. A source of uncertainty with regard to the spread of *S. noctilio,* relates to the potential competition with native bark beetles, native Siricids and stand vigor. Given the potential consequences of *S. noctilio* introduction in the United States, we recommend that pine resources be protected by regulatory means until more is known about its ability to impact U.S. pines.

Central questions to be addressed by future research on *Sirex noctilio* include:

- Can *S. noctilio* displace indigenous bark beetles and Siricids?

- Will *S. noctilio* cause minimal forest damage in the United States, as it does in its native range of Europe and North Africa, or will it become a major forest pest as observed in Southern Hemisphere countries?
- Will native parasitoids effectively use *S. noctilio* as a host?
- Will *S. noctilio* become like *S. cyaneus* F., *e.g.* spread by commerce, be nominally invasive, and currently a minor pest (Arnett, 1985)?

Sirex noctilio can spread through natural or artificial means. Natural spread mechanisms include flight and wind dispersal. Artificial, (*i.e.* human mediated), pathways of *S. noctilio* movement include pine logs and lumber products; large pine branches; and pine stumps. *Sirex cyaneus* is a similar species of woodwasp, with a native range corresponding to that of *S. noctilio*; this species' establishment in the United States was due to commerce and may indicate how S. noctilio could spread without proper safeguards (Smith, 2004).

The development of control strategies for *S. noctilio* originated in Australia, and is being utilized by various countries in the Southern Hemisphere. Control strategies include the restricted movement of infested materials; population monitoring through survey and trap trees; good silvicultural management practices; and the utilization of biological control agents, primarily the parasitic nematode, *Beddingia siricidicola.*

We recommend that similar strategies be implemented for the management of *S. noctilio* in the United States. These strategies will prevent serious economic damage, which would be the result of pest population outbreaks. To implement these strategies, we must determine the extent and the level of *S. noctilio* infestation; prevent the artificial spread of *S. noctilio* in potentially infested materials through treatment and regulated movement of the materials; promote good silvicultural management practices; and utilize the parasitic nematode, *B. siricidicola,* as a biological control agent when, and if, the nematode is approved for release in the United States.

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I. Introduction

Sirex noctilio Fabricius (Hymenoptera: Siricidae) is a member of the horntail wasp family, Siricidae. This species belongs to the subfamily Siricinae and attacks gymnosperms. *Sirex noctilio* is the only species of the woodwasp family that can kill relatively healthy pine trees (Spradbery, 1973; Haugen *et al.*, 1990; Smith and Schiff, 2002). The native range of *S. noctilio* includes Europe, Asia, and North Africa, where it is a minor pest (CPC, 2005; Cielsa, 2003). *Sirex noctilio* is a serious pest of Monterey pine, *Pinus radiata*, plantations in New Zealand, Australia, South Africa, Argentina, Uruguay, and Chile. In Brazil, loblolly pine, *Pinus taeda,* is the primary host of *S. noctilio*.

In September 2004, a Lindgren funnel trap in Fulton, New York (NY) captured an adult *S. noctilio* (Hoebeke *et al.*, 2005). The wasp was positively identified as *S. noctilio* by Richard Hoebeke of Cornell University. Additional delimiting trapping, aerial and ground surveys for potentially infested trees were conducted around Fulton and Oswego NY. As a result, there were additional finds of *S. noctilio*. Because positive trap detections continued to increase in the survey areas, the survey radius expanded 30 to 70 miles from Oswego during the summer and early fall of 2005. The most distant positive find occurred approximately 50 miles southwest of Oswego. Sixty-one of 576 traps were positive for *S. noctilio* in 2005, yielding 85 female specimens. Currently, Oswego is the only location where *S. noctilio* larvae have been collected from infested trees; it is a focal point of the *S. noctilio* infestation in the United States.

The purpose of this pest risk analysis is to examine the risk associated with the woodwasp, *Sirex noctilio* Fabricius and the symbiotic fungus *Amylostereum areolatum* (Fries:Fries) Boidin to the conterminous United States. *Sirex noctilio* and *Amylostereum areolatum* exist in an obligate relationship, with the fungus exhibiting a very rare or absent sexual stage. *Amylostereum areolatum* relies on *S. noctilio* for dispersal and inoculation into the tree and the wasp relies on the fungus for wood breakdown and food (Slippers *et al*., 2003). Due to this obligate relationship, we did not separate the risks associated with the two organisms, but considered them together in the analysis. Topic areas addressing specific issues were added as necessary. We identified areas of uncertainty and made recommendations regarding regulations and future research needs. This information can be used to facilitate the implementation of regulatory practices regarding the wasp with the goal of protecting U.S. pine resources in an efficacious and economically expedient manner.

II. Life History

2.1 Biology and Ecology

Sirex noctilio is a woodwasp that attacks coniferous trees. The adult wasps are large, ranging from 1 to 1.5 inches (2.5 to 4 centimeters) in length, with a metallic (iridescent) blue-black coloration and a stout upturned spine (cornus) at the end of the abdomen. The body of the female wasp is uniform in color with a prominent robust ovipositor located beneath the spine; and the legs are reddish-yellow, with black feet (tarsi). The male wasp has orange middle abdominal segments (segments 3 to 7) and the hind legs are black in color (Smith and Schiff, 2002; Haugen and Hoebeke, 2005). Detailed identification keys for *Sirex noctilio*, and other Siricid species, can be found in Smith and Schiff (2002).

Adult *S. noctilio* wasps emerge during the summer through mid-autumn (Madden, 1988) through circular holes (3 to 8 millimeters, depending on the size of the adult). The wasps are sexually mature upon emergence, with male wasps emerging first and in greater numbers than the females (Neumann and Minko, 1981). A post-emergence rest period of 15 minutes or more is followed by short bursts of flight. Males fly above and around the tree tops on sunny days, and can form small swarms when present in sufficient numbers. *Sirex noctilio* females have an initial flight of 100 meters or more after emergence, followed by shorter noisy flights similar to the male wasps (Morgan and Stewart, 1966). The females will then move up the trunk of the tree and begin inserting the ovipositor; females prefer stressed trees , which may be the result of drought, nutrition deficiency, unsuitable site selection, damage from storms, and climate, organisms, or suppression (Neumann *et al.*, 1987). *Sirex noctilio* attack both plantation and wild pine trees under stressed conditions. The volatiles released from attractive trees are monoterpene hydrocarbons and ketones (Simpson and McQuilkin, 1976). The exploratory insertion of the ovipositor assesses the suitability of the host tree. If the osmotic pressure of the tree is high, greater than 1210 kPa, the female will deposit only phytotoxic mucus (Madden, 1974); the mucus will cause a disruption in the functioning of the tree's needles and respiration (Coutts, 1969b), weakening the tree, and making it susceptible to future *Sirex* infestations. The mucus secretion is a blend of polysaccharides enzymes, oxidases and proteolases (King, 1966; Fong and Crowden, 1976) produced by glands and stored in a reservoir (Spradbery, 1973). *Sirex noctilio* has a larger mucus gland compared to other members of the Siricidae family (Spradbery, 1977).

Sirex noctilio is arrhenotokous, meaning that unmated females produce only male offspring, while mated females produce either male or female offspring (Taylor, 1981). In suitable trees, (*i.e.*, trees with low osmotic pressure 200-810 kPa), the female wasp will make multiple drills and deposit egg(s), spores of the fungi *Amylostereum areolatum,* and mucus (Neumann *et al.*, 1987). *Sirex noctilio* will oviposit in wood with a moisture content ranging from 20-200 percent oven-dry weight (Morgan and Stewart, 1966). *Amylostereum areolatum* is a saprotrophic decay fungi that causes extensive rot within infected trees over time, spreading up to 2.8 meters in ten years (Vasiliauskas *et al.*, 1998). *Amylostereum areolatum* and *S. noctilio* have a symbiotic relationship; the fungi is deposited into the tree by the wasp, and then dries and breaks down the wood into digestible hypal fragments that the larvae feed and develop on (Neumann *et al.*, 1987). Slippers *et al*. (2003) completed a review of the symbiotic association between *Amylostereum* and woodwasps. Adult *S. noctilio* do not feed and have a short life span ranging from a few days to a few weeks. The females can sometimes be found dead on trees with the ovipositor still inserted (Taylor, 1981). The number of eggs per female *S. noctilio* is dependent on the size of the wasp, *e.g.*, 212 eggs were found per average size female in Victoria, Australia (Neumann *et al.*,, 1987). The mucus and *A. areolatum* work in conjunction to dry the wood of moisture to create a more suitable environment for eggs to hatch (30 to 70 percent less than saturated) (Neumann and Minko, 1981).

The eggs of *S. noctilio* are elongate-oval (1.0-1.5 mm x 0.2-0.3 mm), white, and soft and smooth in appearance (Morgan, 1968). They are deposited into the xylem (or outer sapwood of the tree) within drill shafts bored by the ovipositor (Madden, 1988). The oviposition depth is reported to be 10-20 millimeters into the sapwood, but can be influenced by the width of the growth rings in the tree (Neumann and Minko, 1981; Madden 1988). In Australia, eclosion of the larvae from the eggs typically occurs in 14 days, but the length of time can be delayed and affected by environmental conditions (Neumann *et al.,* 1987).

Larvae are creamy-white with deep segmentations, s-shaped and uniform in diameter (Neumann and Minko, 1981). The average body length and thoracic width of the *S. noctilio* larvae is 1.06 by 0.26, and 27.17 by 6.23 millimeters for first and sixth instars, respectively (Neumann and Minko, 1981). *Sirex noctilio* typically passes through six to seven larval instars before pupating, but the number of instars can range from 5-12 (Neumann and Minko, 1981). The first instar larvae move up or down from the egg gallery along the wood tracheid line 8 to 12 millimeters from the bark (Morgan and Stewart, 1966). The second instar female larvae acquire mycelium of *A. areolatum* from the infected wood and store it in hypopleural organs (Neumann and Minko, 1981). At the end of the third instar larval stage, *S. noctilio* will have progressed 15 to 20 millimeters in the wood from the initial egg chamber (Morgan and Stewart, 1966). The fourth and fifth instar larvae generally turn inward toward the heartwood (center) about 60 mm, creating a meandering mine that turns up and out toward the surface of the wood (Morgan and Stewart, 1966). The total length of the larval mine is reported to be 120-150 mm long, expanding in diameter as it progresses, with the pupation chamber constructed 50 mm from the surface of the tree (Morgan and Stewart, 1966). The larval tunnel is filled with a course frass consisting of chewed wood and excrement. A pre-pupal period of 20 to 28 days is typical (Morgan and Stewart, 1966), but the length is influenced by environmental conditions. The pupae and newly molted (teneral) adult retain the cast off skin (exuviae) from pre-pupal and pupal molts; this skin acts as a cap over the distal third of the abdomen until the adult wasp begins emergence. The cap helps the transfer of the fungus to the female wasp (Morgan and Stewart, 1966).

Figure 1. Wood Infested with *Sirex noctilio* Larvae. Paula Klasmer, Instituto Nacional de Tecnologia Agropecuaria, www.forestryimages.org

III. Geographic Distribution

3.1 Worldwide Distribution

Sirex noctilio occurs in the following European countries where it is considered a minor pest: Austria, Belgium, Cyprus, Czechoslovakia (former), Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Norway, Poland, Portugal, Azores, Romania, Russian Federation (localized), Serbia, Spain (Canary Islands), and the United Kingdom (CPC, 2005). In Asia and Africa, *S. noctilio* occurs in Mongolia and South Africa (CPC, 2005). In South America, *S. noctilio* is a major pest in Argentina, Brazil (Parana, Rio Grande Do Sul, and Santa Caterina), Uruguay, and Chile (CPC, 2005). The infestation of woodwasp in Chile is confined and under quarantine controls (CPC, 2005). In Oceania, *S. noctilio* occurs in Australia and New Zealand (CPC, 2005). The worldwide geographic distribution of *Sirex noctilio*, represented by country or region, is illustrated in Figure 2.

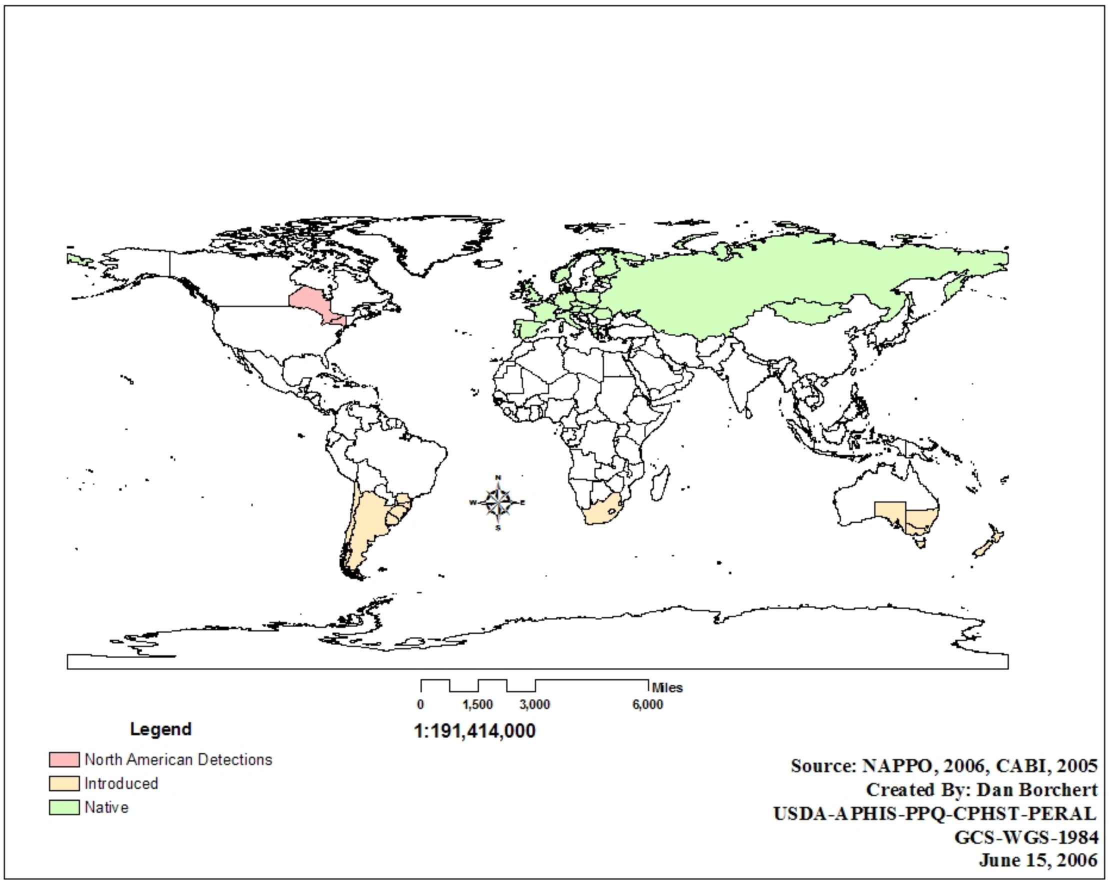

Figure 2. Reported Worldwide Distribution of *S. noctilio* (CPC, 2005).

3.2 Current Distribution in the United States and Canada, and History of Introduction

To date, *Sirex noctilio* has been detected in five New York counties: Oswego, Cayuga, Onondaga, Seneca and Wayne. It has been found in the Canadian province of Ontario, Prince Edward, Leeds and Grenville United, and Waterloo and Durham counties (NAPPO, 2006). Figure 3 displays the United States and Canadian counties in which *S. noctilio* has been detected.

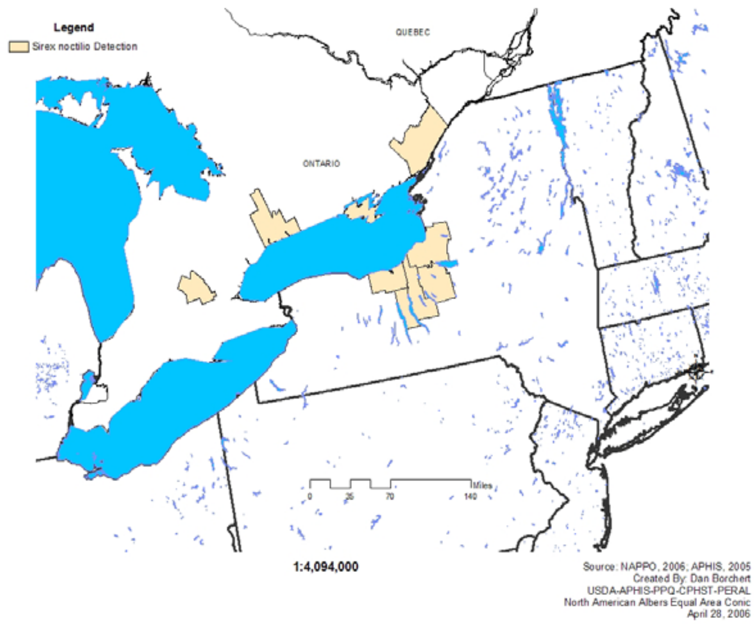

Figure 3. Counties in North America where *S. noctilio* has been detected (NAPPO, 2006; APHIS, 2006a).

IV. Consequences of Introduction

4.1 Risk Element #1. Habitat Suitability

Rating	Numerical Score	Explanation
High	3	Attacks and survives on hosts in 4 or more plant hardiness zones
Medium	2	Attacks and survives on hosts in 2 or 3 plant hardiness zones
Low	1	Attacks and survives on hosts in a single plant hardiness zone

Rank: High

Sirex noctilio occurs in USDA Plant Hardiness Zones 3 to 10 in Europe (Spradbery and Kirk, 1978; CPC, 2005; Kelley, 1998), 8 to 10 in Australia (Neumann *et al*., 1987; Dawson, 1991), New Zealand (Liddle wonder, 2002; CPC 2005), 6 to 10 in South America (CPC, 2005; Plant Ideas, 2006), and 7 to 9 in South Africa (CPC, 2005; Backyard Gardener, 2006).

A degree day model for *S. noctilio* (based on the work of Madden (1981)) was developed using the NAPPFAST system (Borchert and Magarey, 2005). The model demonstrated that *S. noctilio* could complete one generation (life-cycle) of development per year in much of the United States, with generation development taking potentially two years at higher latitudes (Figure 4). A CLIMEX prediction model for *S. noctilio* potential distribution found that many areas of the United States, Canada and Mexico were suitable for establishment (Carnegie *et al*., 2006). Consequently, host distribution will probably limit *S. noctilio*'s distribution, for example, the distribution of pine hosts in the United States indicates that *S. noctilio* can establish in USDA Plant Hardiness Zones 3 to 9 (Figures 4, 5 and 6). This confers a rank of **High** to *S. noctilio* with regard to Habitat Suitability in the United States (USDA-ARS, 1990).

Below is a list of the regions and their pine host distribution, as per the USDA Plant Hardiness Zones: Northeastern and North Central States, pine host distribution Zones 3 to 6 (Figures 5, 6 and 7) (USDA-ARS, 1990); the Southern States, pine host distribution Zones 6 to 9; and the Western States, pine host distribution Zones 3 to 8. This confers a rank of **High** to *S. noctilio* with regard to Habitat Suitability in each of these regions.

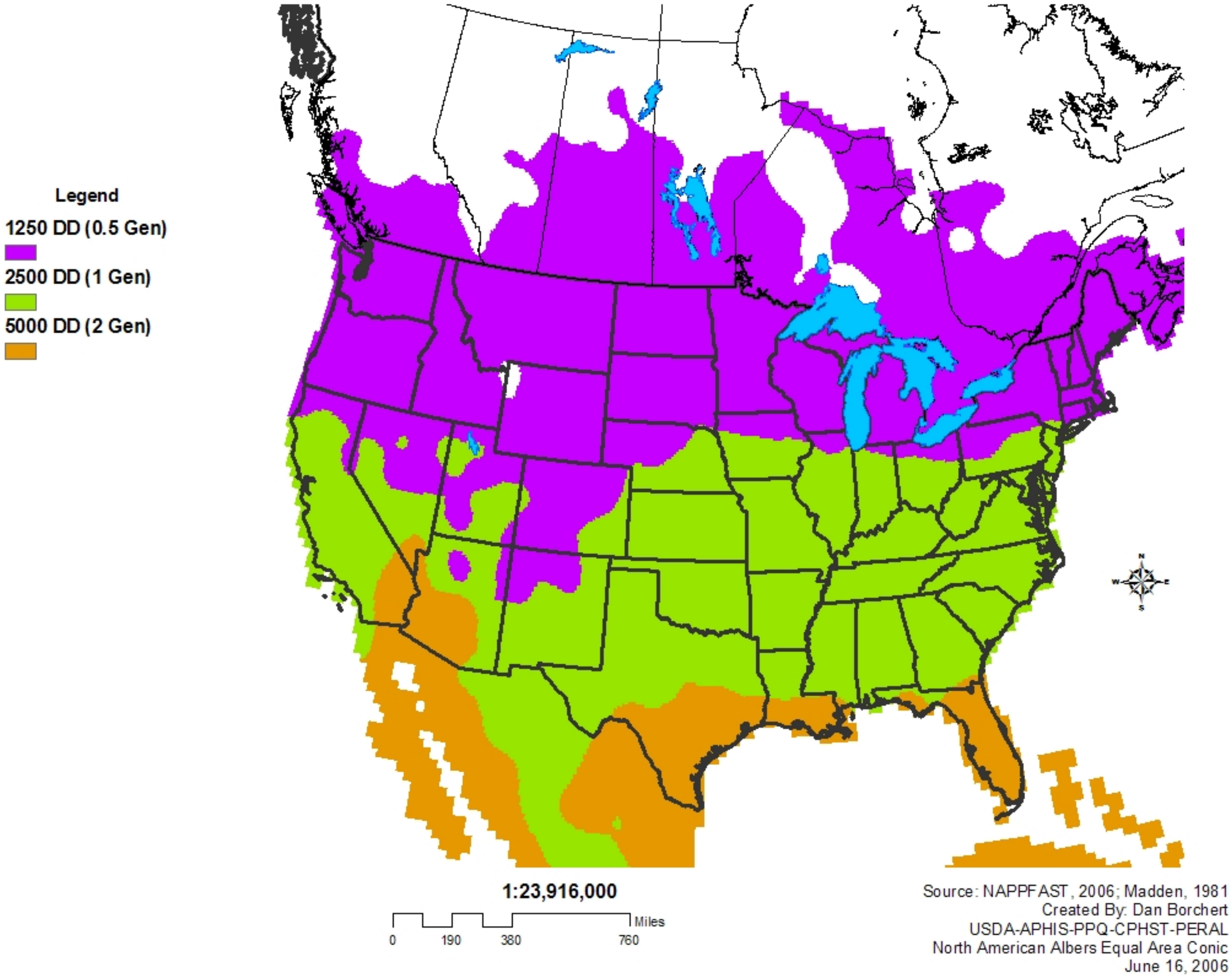

Figure 4. Generation Potential Estimated for *Sirex noctilio* in the United States. (NAPPFAST degree day models with a base developmental temperature of 6.8 C and 2500 DD estimate for the completion of one generation.)

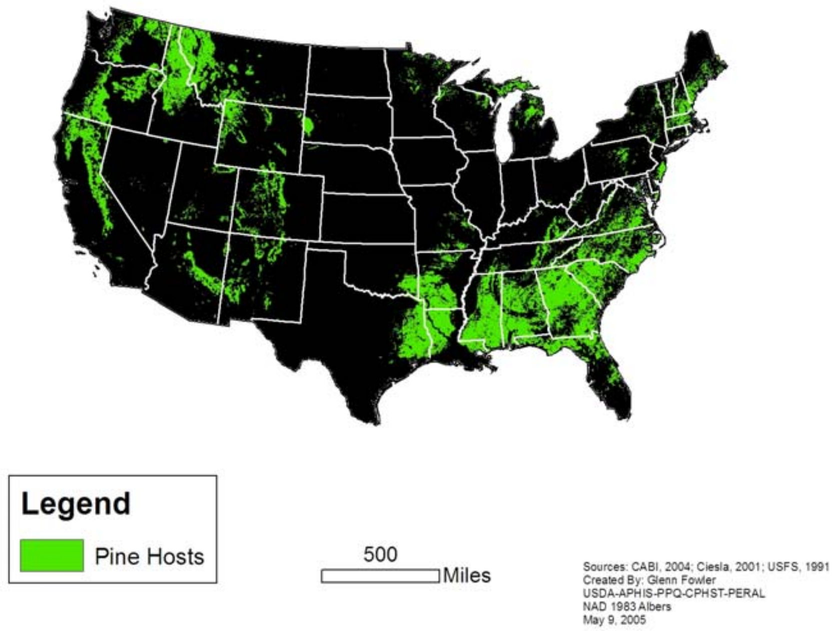

Figure 5. United States *S. noctilio* Pine Hosts Distribution on Timberland (CPC, 2005; USDA-USFS, 1991).

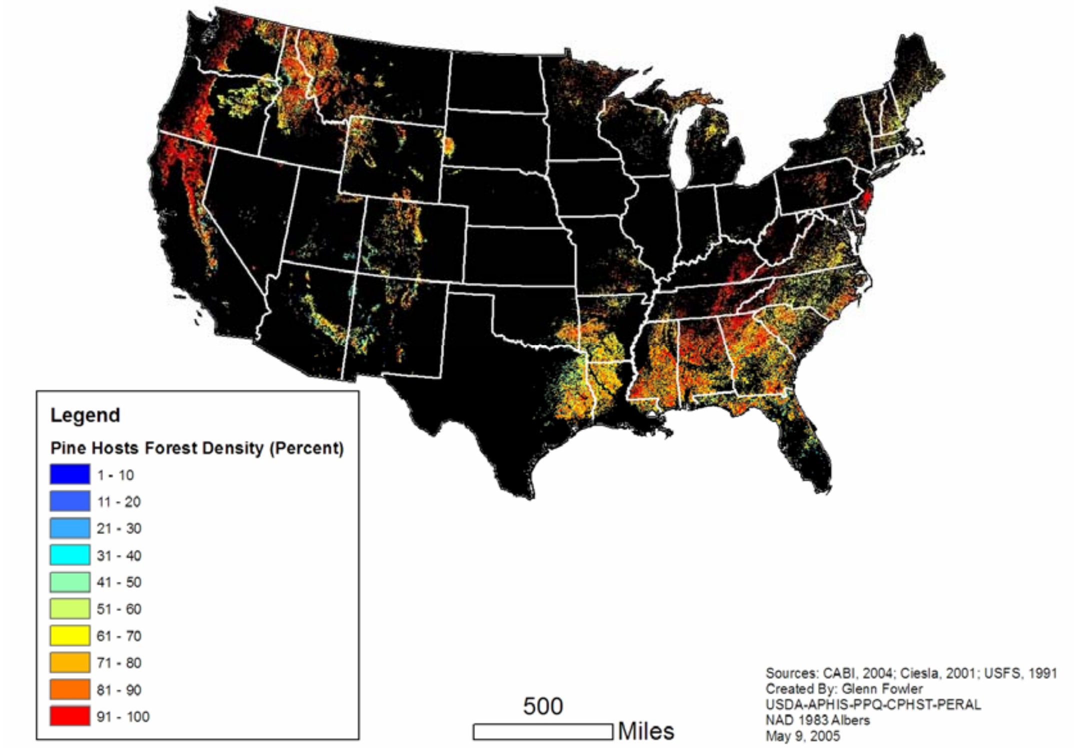

Figure 6. ***Sirex noctilio*** **Pine Hosts Density in the United States (CPC, 2005; USDA-USFS, 1991).**

Pine hosts density is reported in percent forest cover in timberland (USDA-USFS, 1991).

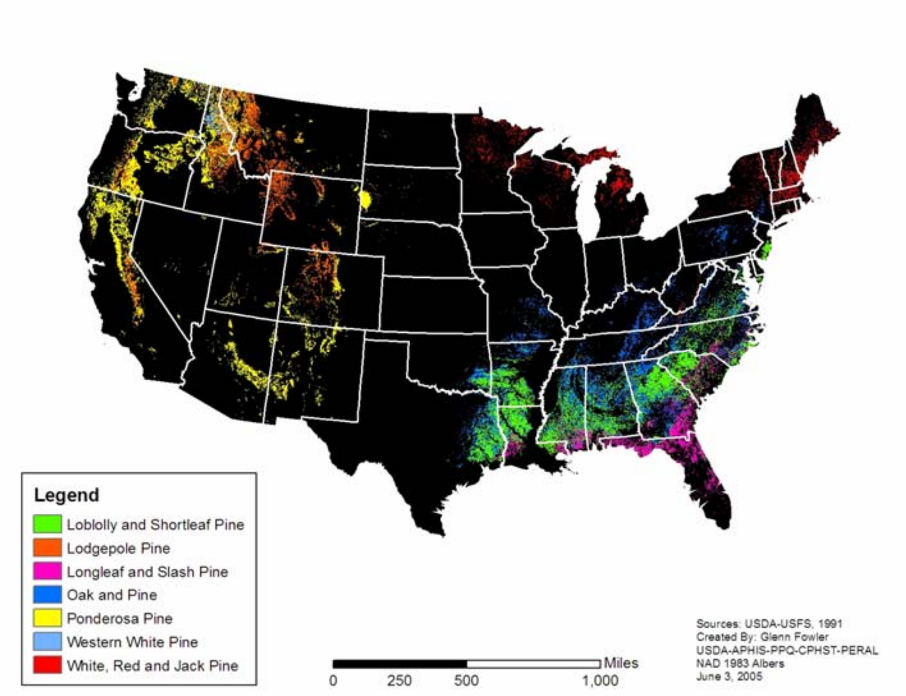

Figure 7. Major Pine Forest Types in the Conterminous United States (USDA-USFS, 1991).

4.2 Risk Element #2: Host Range

Rating	Numerical Score	Explanation
High	3	Insect attacks multiple species within multiple host families
Medium	2	Insect attacks multiple species within a single host family
Low	1	Insect attacks only a single species or multiple species within a single genus

Rank: Low

Pines are the principal hosts of *S. noctilio*, and the wasp can complete its life-cycle on multiple species within this genus (Chrystal, 1928; CPC, 2005; Spradberry and Kirk, 1978, Morgan and Stewart, 1966). The following *Pinus* species are hosts of *S. noctilio*: *P. radiata, P. nigra calabrica, P. nigra austriaca, P. ponderosa, P. elliotii, P. patula, P. contorta, P. caribaea, P. pinaster, P. attenuata, P. muricata, P. banksiana, P. canariensis, P. densiflora, P. echinata, P. halepensis, P. jeffreyi, P. palustris, P. pinaster, P. pinea, P. brutia, P. sylvestris* and *P. taeda* (Morgan and Stewart, 1966; CPC, 2005; Madden 1988; Spradberry and Kirk, 1978). *Sirex noctilio* has been collected from *P. strobis* (white pine) and *P. resinosa* (red pine) in Oswego, New York. *Sirex noctilio* has also been recorded on other genera of conifers, such as *Larix* (Larch), *Pseudotsuga* (Douglas Firs), *Picea* (spruce) and *Abies* (firs) (Morgan and Stewart, 1966; Madden, 1988, Spradberry and Kirk, 1978; Chrystal, 1928). *Sirex noctilio* attacked *Larix* and *Pseudotsuga* in New Zealand when moribund (Morgan and Stewart, 1966), while Chrystal

(1928) reported that it "sometimes attacked silver firs and very occasionally spruce." In an extensive survey by Spradberry and Kirk (1978), 99 percent of the 8,265 *S. noctilio* wasps collected were from *Pinus* spp.; the remaining 0.8 percent and 0.05 percent were found on *Picea* and *Abies* spp., respectively. Based on this information, we consider pines to be the only viable hosts with regard to risk scoring. We confer a rating of **Low** to *S. noctilio* with regard to Host Range; however, the genus *Pinus* is a large, diverse and important genus of plants, and *S. noctilio* has been reported to attack numerous species within this genus.

4.3 Risk Element #3: Dispersal Potential

	Dispersal Considerations	**Source**
X	Consistent and prolific reproduction	Madden, 1988
	Rapid growth to reproductive maturity	
	Wide range of hosts	
X	Tolerant to temperature extremes	Spradbery and Kirk, 1978
	Phoresy, *i.e.* dispersal by utilizing another organism	
	Ability to utilize different host during different life stages	
	Social behavior	
	Migratory behavior/swarming	
X	Alteration of generations/parthenogenesis/phase polymorphism	Taylor, 1981
X	Can reside within host	Neumann *et al.*, 1987
	Diapause/overwintering	
X	Stress tolerance, including ability to resist insecticides and/or adverse weather conditions	Fisher, 1955
	Lack of natural control agents	
X	Natural dispersal	Morgan and Stewart, 1966 Neumann *et al.*, 1987
X	Wind dispersal	Morgan and Stewart, 1966
	Water dispersal	
	Machinery dispersal	
	Animal dispersal	
X	Human dispersal	USDA, 1992

Rating	Numerical Score	Explanation
High	3	Insect has high reproductive potential (*e.g.*, prolific egg production, high survival rate), AND highly mobile life stages (*i.e.*, capable of moving long distances aided by wind, water or vectors)
Medium	2	Insect has either high reproductive potential OR highly mobile life stages
Low	1	Insect has neither high reproductive potential nor highly mobile life stages

Rank: High

Sirex noctilio females lay an average of 212 eggs (Neumann *et al.*, 1987); a single female can produce 53 female offspring (Neumann and Minko, 1981). *Sirex noctilio* are arrhenotokous parthenogenic, meaning that unmated females produce only male offspring, while mated females can produce either male or female offspring (Taylor, 1981).

The immature stages of *S. noctilio* remain within the wood during development; survival during larval development is affected by the ability of the tree to compartmentalize the fungus and larvae; parasitization of the wasp by natural enemies; moisture content of the wood; and the amount of resin. In newly invaded areas, the survival rate is generally high (Neumann and Minko, 1981; Taylor, 1981).

The maximum yearly dispersal rate of *Sirex noctilio* observed in Australia is 30 to 40 km (18 to 25 miles) and 48 kilometers (29.8 miles) per year in South Africa (Carnegie *et al.*, 2006). In flight tunnel experiments, large females have been reported to fly up to 160 kilometers (100 miles) (Taylor, 1981). Observation shows that when female wasps emerge later in the season, or in areas where resources are limited, they disperse farther than early emerging females. Male wasps remain near the initial emergence area unless spread by wind (Morgan and Stewart, 1966).

Sirex noctilio can be spread by humans through the movement of infested material, *e.g.* logs. *Sirex noctilio* has been observed ovipositing on freshly cut logs on logging trucks in New Zealand, often continuing to attack the logs during transit (Morgan and Stewart, 1966). The immature stages develop within the wood and are difficult to detect, even in rough sawn lumber (USDA, 1992; Fisher, 1955). The wood wasp *Sirex cyaneus*, already well-established in the United States, is a likely example of an invasive species that followed a similar pathway, and has been reported to be moved in commerce (Arnett, 1985).

4.4 Risk Element #4: Economic Impact

Impact Categories include reduced commodity yield (*e.g.*, feeding, disease vector); lower commodity value (*e.g.*, by increasing costs of production, lowering the market price, or a combination or, if not an agricultural insect, by increasing costs of control); loss of markets (foreign or domestic) due to presence of a new quarantine pest.

Rating	Numerical Score	Explanation
High	3	Insect causes all three of the above impacts, or causes any one impact over a wide range of economic plants, plant products or animals (over five types)
Medium	2	Insect causes any two of the above impacts, or causes any one impact to three or four types of economic plants, plant products, or animals
Low	1	Insect causes any one of the above impacts to one or two types of economic plants, plant products, or animals
Nil	0	Insect causes none of the above impacts

Rank: High

Table 1. Annual U.S. Christmas Tree Production in the Northeastern and North Central United States (Helmsing, 2004; Michigan Ag Connection, 2005; Olsen pers. comm., 2005; USDA-ERS, 1990; USDA-NASS, 2002).

State	Sales	Proportion of Trees Sold (Pines)	Estimated Annual Pine Christmas Tree Sales
Connecticut	3,407,000	0.10	340,700
Delaware	401,000	0.41	164,410
Iowa	1,424,000	0.95	1,352,800
Illinois	7,633,000	0.89	6,793,370
Indiana	2,775,000	0.83	2,303,250
Massachusetts	1,800,000	0.16	288,000
Maryland	2,313,000	0.75	1,734,750
Maine	2,293,000	0.10	229,300
Michigan	30,411,000	0.21	6,386,310
Minnesota	11,855,000	NA	NA
Missouri	1,843,000	0.98	1,806,140
New Hampshire	2,028,000	0.14	283,920
New Jersey	3,852,000	0.23	885,960
New York	11,759,423	0.16	1,881,508
Ohio	9,323,000	0.83	7,738,090
Pennsylvania	31,193,000	0.41	12,789,130
Rhode Island	658,000	0.24	157,920
Vermont	2,372,000	0.07	166,040
West Virginia	1,182,000	0.66	780,120
Wisconsin	23,412,000	0.69	16,154,280
Total	**151,934,423**	**0.41**	**62,235,998**

Table 2. Annual Coniferous Evergreen Nursery Data for Selected U.S. States (USDA-NASS, 2004). Average values based on 2000 and 2003 nursery data reported. Nursery data reported for operations with annual sales greater than $100,000.

State	Producers	Plants Sold	Sales
Alabama	56	2,104,500	8,236,500
California	123	5,610,000	64,606,500
Connecticut	26	2,843,000	25,080,500
Florida	144	2,649,500	20,389,500
Georgia	47	2,127,000	11,653,500
Illinois	82	665,500	19,063,500
Michigan	79	2,603,500	33,264,000
New Jersey	94	1,550,000	25,726,500
New York	52	530,000	9,866,000
North Carolina	125	1,607,000	19,776,000
Ohio	79	1,578,000	27,509,500
Oregon	161	10,601,500	97,569,500
Pennsylvania	96	1,093,500	27,986,500
South Carolina[1]	37	818,000	4,547,000
Tennessee	93	1,080,000	9,793,000
Texas	47	884,500	8,186,000
Virginia[2]	32	708,000	9,535,000
Washington	39	637,000	7,298,500
Total	**1,412**	**39,690,500**	**430,087,500**

[1]South Carolina only reported data for 2000
[2]Virginia only reported data for 2003

An attack by *S. noctilio* can cause tree mortality, in addition to a reduction in commodity value, which is an effect of the deposition of the phytotoxic mucus and the introduction of *A. areolatum* (Taylor, 1981). The damage caused by an attack could pose an economic threat to the U.S. softwood timber industry. The timber industry in the United States produces large quantities of timber; has timber processing mills throughout the country; and has annual sales of logs, lumber, pulpwood and veneer valued at nearly $20 billion (LDAF, 2000; Prestemon *et al*., 2005; USDA-USFS, 2001, 2003; USDC, 1999a, 1999b, 1999c) (Figure 12; Tables 6, 7, 8 and 9).

Sirex noctilio can successfully attack stressed trees (CPC, 2005; Neumann *et al.*, 1987). Common causes of tree stress include overcrowding, drought, nutrition deficiency, unsuitable site selection, damage from climate or other organisms, or suppression (Neumann *et al.*, 1987). From 1987 to 1989 southeastern Australia and southwestern Victoria, experienced severe outbreaks of *S. noctilio* in plantations of *Pinus radiata*; these outbreaks cost an estimated $10 to 12 million in losses (Haugen *et al.*, 1990).

When evaluating the economic effects caused by the introduction of *S. noctilio* into three areas of the western United States (USDA, 1992), the best and worse case scenarios estimated losses between $24 to 131 million. Of the five wood pests examined in this economic evaluation, *S. noctilio* had the greatest potential economic impact.

Sirex noctilio is a quarantine pest in the United States, Canada and Japan. Phytosanitary certificates and treatments will likely be necessary for the movement of pine logs from areas identified as infested with *S. noctilio* (CPC, 2005).

Table 3. 1996 United States Softwood Production in Thousand Cubic Feet (MCF) by Region (USDA-USFS, 2001).

United States Region	Saw Logs	Veneer Logs	Pulpwood	All Products
Northeast North Central	336,542	3,075	369,044	815,874
South	2,721,782	736,174	2,399,152	6,154,838
West	2,099,934	384,689	82,472	3,065,488
Total	**5,158,258**	**1,123,938**	**2,850,668**	**10,036,200**

Table 4. Value of Selected Softwood Commodities in the Northeastern and North Central States that Could be Affected by *S. noctilio* (LDAF, 2000; USDA-USFS, 2001, 2003; USDC, 1999a, 1999b, 1999c).

State	Softwood Logs and Bolts[1]	Softwood Lumber[1,3]	Softwood Veneer[1,4]	Softwood Pulpwood Production[2]	Total
Connecticut	NA	NA	NA	60,778	60,778
Delaware	NA	NA	NA	1,042,405	1,042,405
District of Colombia	NA	NA	NA	NA	NA
Illinois	NA	NA	NA	85,282	85,282
Indiana	NA	2,985,000	NA	260,529	3,245,529
Iowa	NA	NA	NA	NA	NA
Maine	128,299,000	262,045,000	NA	29,551,781	419,895,781
Maryland	3,210,000	29,220,000	NA	2,144,664	34,574,664
Massachusetts	NA	10,809,000	NA	241,633	11,050,633
Michigan	2,659,000	24,857,000	NA	10,000,351	37,516,351
Minnesota	4,689,000	43,997,000	NA	11,742,430	60,428,430
Missouri	NA	2,891,000	NA	3,225	2,894,225
New Hampshire	5,368,000	110,054,000	NA	5,125,285	120,547,285
New Jersey	NA	NA	NA	119,913	119,913
New York	25,000,000[5]	40,000,000[5]	NA	6,622,404	28,840,404
Ohio	NA	5,406,000	NA	486,798	5,892,798
Pennsylvania	NA	9,254,000	NA	1,518,974	10,772,974
Rhode Island	NA	NA	NA	88,938	88,938
Vermont	NA	NA	NA	4,173,256	4,173,256
West Virginia	NA	6,311,000	NA	1,110,557	7,421,557
Wisconsin	NA	24,224,000	NA	17,698,846	41,922,846
Total	**169,225,000**	**572,053,000**	**NA**	**92,078,047**	**790,574,047**

[1]Values in 1997 dollars
[2]Values based on the average 1996 Louisiana southern pine pulpwood price per cord adjusted to 1998 dollars.
[3]Refers to lumber that is not edge worked and not manufactured from purchased lumber (USDC, 1999b).
[4]Includes veneer backed with cloth, paper or another flexible material (USDC, 1999c).
[5] NYS Forest Products Timber Estimate 2004 (Crawford, 2006)

Table 5. Value of Selected Softwood Commodities in the Southern States that could be Affected by *S. noctilio* (LDAF, 2000; USDA-USFS, 2001, 2003; USDC, 1999a, 1999b, 1999c).

State	Softwood Logs and Bolts[1]	Softwood Lumber[1,3]	Softwood Veneer[1,4]	Softwood Pulpwood Production[2]	Total
Alabama	67,078,000	803,149,000	36,721,000	117,562,990	1,024,510,990
Arkansas	152,623,000	817,759,000	12,627,000	35,409,337	1,018,418,337
Florida	77,317,000	244,798,000	NA	81,277,478	403,392,478
Georgia	96,614,000	998,557,000	52,696,000	119,639,174	1,267,506,174
Kentucky	NA	14,057,000	NA	938,390	14,995,390
Louisiana	107,022,000	412,891,000	33,950,000	64,595,774	618,458,774
Mississippi	271,459,000	937,552,000	28,866,000	58,912,520	1,296,789,520
North Carolina	122,671,000	571,646,000	11,255,000	54,777,797	760,349,797
Oklahoma	NA	129,014,000	NA	8,145,651	137,159,651
South Carolina	38,898,000	532,022,000	NA	63,356,945	634,276,945
Tennessee	NA	6,046,000	NA	12,692,221	18,738,221
Texas	210,876,000	424,550,000	9,607,000	32,336,410	677,369,410
Virginia	10,642,000	234,115,000	6,310,000	31,883,749	282,950,749
Total	**1,155,200,000**	**6,126,156,000**	**192,032,000**	**681,528,435**	**8,154,916,435**

[1]Values are in 1997 dollars.
[2]Values based on the average 1996 Louisiana southern pine pulpwood price per cord adjusted to 1998 dollars.
[3]Refers to lumber that is not edge worked and not manufactured from purchased lumber (USDC, 1999b).
[4]Includes veneer backed with cloth, paper or another flexible material (USDC, 1999c).

Table 6. Value of Selected Softwood Commodities in the Western States that Could be Affected by *S. noctilio* (LDAF, 2000; USDA-USFS, 2001, 2003; USDC, 1999a, 1999b, 1999c).

State	Softwood Logs and Bolts[1]	Softwood Lumber[1,3]	Softwood Veneer[1,4]	Softwood Pulpwood Production[2]	Total
Arizona	NA	45,962,000	NA	339,814	46,301,814
California	154,140,000	1,758,190,000	60,169,000	NA	1,972,499,000
Colorado	NA	35,359,000	NA	NA	35,359,000
Idaho	245,711,000	823,895,000	31,398,000	4,833,801	1,105,837,801
Kansas	NA	NA	NA	NA	NA
Montana	115,308,000	509,193,000	NA	1,182,282	625,683,282
Nebraska	NA	NA	NA	NA	NA
New Mexico	NA	NA	NA	371,569	371,569
Nevada	NA	NA	NA	NA	NA
North Dakota	NA	NA	NA	NA	NA
Oregon	993,860,000	2,418,176,000	392,057,000	2,182,786	3,806,275,786
South Dakota	NA	NA	NA	NA	NA
Utah	NA	13,867,000	NA	NA	13,867,000
Washington	1,331,068,000	1,610,913,000	80,165,000	6,170,894	3,028,316,894
Wyoming	2,008,000	73,182,000	NA	NA	75,190,000
Total	**2,842,095,000**	**7,288,737,000**	**563,789,000**	**15,081,146**	**10,709,702,146**

[1]Values are in 1997 dollars.
[2]Values based on the average 1996 Louisiana southern pine pulpwood price per cord adjusted to 1998 dollars.
[3]Refers to lumber that is not edge worked and not manufactured from purchased lumber (USDC, 1999b).
[4]Includes veneer backed with cloth, paper or another flexible material (USDC, 1999c).

The regional distribution of U.S. forests we used is based on the USFS classification system; this may affect their susceptibility to damage by *S. noctilio*. This USFS system divides the conterminous United States into eight regions (Figure 8) (USDA-USFS, 2005). The Northeastern and North Central States are covered by region R9 (eastern); the South is covered by region R8; and the Western States are divided into six regions (R1-R6).

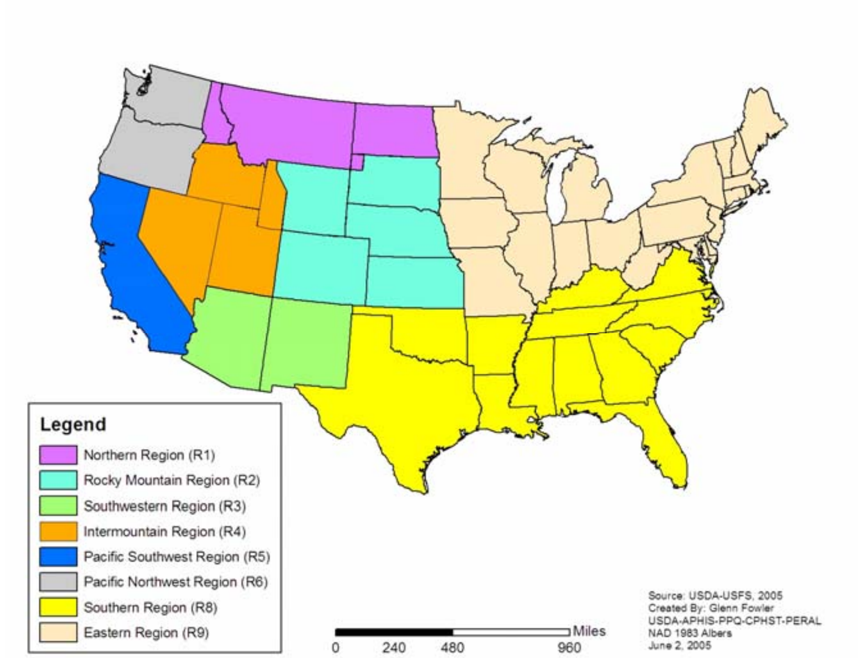

Figure 8. USFS Regions

The Southern States produce 60 percent of the nation's timber (USDA-USFS, 2003). This region produces more timber than any other country. Softwood (especially southern pine) forestry is a major source of revenue in the South (Table 3). Over the past 50 years, the South has surpassed the Western States as the nation's leading producer of softwood timber and pulpwood (USDA-USFS, 2003) (Table 3) for the following reasons: technological advances in southern pine manufacturing and treatment; short rotation periods; and increased demand for strong pulp fiber (Adams, 1995; Helms, 1995; Tesch, 1995; USDA-USFS, 2003; Walker, 1995). The increase in softwood timber and pulpwood production results in an increased investment in southern pine production and advances in stand management and tree genetics (USDA-USFS, 2003). Models forecasting southern timber trends through the year 2040 have predicted: 1) softwood timber prices will increase; 2) there be an increase in softwood timber production; and 3) pine plantation areas (in the South) will increase by 67 percent (USDA-USFS, 2003).

Loblolly pine (*Pinus taeda*) is the most important pine species for timber and pulpwood production in the Southern States; it comprises over 50 percent of pine in this region (UFL, No Date; About Inc., 2005). Other southern pine species that *S. noctilio* can affect (besides loblolly pine) include longleaf pine, shortleaf pine, and slash pine (USDA-USFS, 1991) (Figure 6).

Overall, the West produces less softwood timber than the Southeast, and more than the Northeast and North Central States (Table 3). The total value of western softwood timber products analyzed in this assessment is the highest in the United States, (*i.e.* approximately $11 billion annually in logs, lumber, veneer and pulp products) (Table 6); this may be due, in part, to the large quantity of high priced softwood timber, (*e.g.* Douglas fir, harvested in Oregon and Washington), and the rising timber prices, due to lower forestry investments (Helms, 1995; Tesch, 1995; Skog and Risbrudt, 1982; USDA-USFS, 2003).

Compared to the West and South, the Northeastern and North Central States have a lower density and distribution of pine hosts (Figures 5, 6 and 7). Consequently, the softwood timber industry in the Northeast and North Central States is not as large as the Southern or Western States (Tables 3, 4, 5 and 6). White pine is one of the major forest types in the Northeast and North Central States (Figure 7).

Given the current and future economic value of pine resources, and the uncertainty regarding what impact *S. noctilio* will have if and when it spreads from the current area of detection, it is prudent to protect pine resources by the most efficacious means available. The recommendation section of this document includes suggestions with regard to protection methodologies.

4.5 Risk Element #5: Environmental Impact

Impact categories include effects on ecosystem processes (*e.g.*, increases fire risk due to feeding or disease transmission); impacts on the natural community composition (*e.g*., reduce bio-diversity, affect native populations, and affect endangered or threatened species); and the impacts on the community structure (*e.g*., change density of a canopy layer, eliminate or create a canopy layer). Other impacts include those on human health, such as disease transmission or the production of allergens; and the stimulation of control programs, including toxic chemical pesticides or the introduction of a non-indigenous biological control agent.

Rating	Numerical Score	Explanation
High	3	Three or more of the above.
Medium	2	Two of the above.
Low	1	One of the above.
Nil	0	None of the above.

Rank: Medium

Sirex noctilio has caused significant damage to plantations of *Pinus radiata* D. Dom (Monterey pine) in the Southern Hemisphere (Madden, 1988; Carnegie *et al.*, 2005). *Pinus radiata* is listed as Endangered by the World Conservation Union (IUCN) Conifer Specialist Group, indicating that it is "facing a very high risk of extinction in the wild in the near future" (Earle, 2005). The native *P. radiata* occurs in three locations in central coastal California (Earle and Frankis, 1999); these forests have significant ecological and genetic resource value (Ciesla, 2003).

In Australia and other countries in the Southern Hemisphere where *S. noctilio* is a pest, the neotylenchid nematode, *Beddingia* (=*Delandenus) siricidicola*, is a biological control agent. This parasitic nematode was first isolated from *S. noctilio* in New Zealand in 1962 (Bedding and Akhurst, 1974). The APHIS *Sirex* Science Advisory panel recommends the initiation of a program to import and deploy *B. siricidicola* as quickly as possible (APHIS, 2006b).

Sirex noctilio attacks live pine trees, which results in rapid wilting of the crown needles and tree death (Eldrige and Taylor, 1989); however, in their native range siricids are considered to be of minor environmental importance (Smith and Schiff, 2002; Slippers *et al*., 2003). *Sirex noctilio* is an "essentially secondary, opportunistic wood-boring pest," that, in small numbers, may be useful in killing unwanted trees; however, these populations must be maintained, or damage can be significant (Neumann *et al.*, 1987).

4.6 Cumulative Risk Element Score

Cumulative Risk Element Score	Risk Rating	Risk Score
5-7	Low	1
8-11	Medium	2
12-15 (Habitat Suitability = 3) + (Host Range = 1) + (Dispersal Potential = 3) + (Economic Impact = 3) + (Environmental Impact = 2) = 12	High	3

Rank: High

With regard to cumulative risk, *Sirex noctilio* scored **High**. It scored High for Habitat Suitability, Dispersal Potential and Economic Impact. Environmental Impact scored Medium for the U.S.– based on the potential impact of the woodwasp related to the endangered *Pinus radiata*, and the introduction of a non-native species of nematode, *Beddingia siricidicola*, for use as a biological control agent. *Sirex noctilio* scored Low with regard to Host Range due to its preference for species in the genus *Pinus*. These scores indicate that *S. noctilio* could pose a serious potential economic threat to the U.S. forestry industry.

V. Pathways of Introduction

5.1 Natural Spread

Based on survey trapping conducted in 2005, *S. noctilio* has been found in five counties in the United States and four counties in Canada (APHIS, 2006a; NAPPO, 2006); a delimiting survey has not yet been completed. A grid trapping plan, extending 150 miles in radius from Oswego, New York, has been developed and will be deployed in 2006. *Sirex noctilio* is capable of dispersing large distances, 30 to 40 kilometers (18 to 25 miles), each year (Carnegie *et al*., 2006); this demonstrated ability allows it to span areas of low density pine host plantings, such as those in New South Wales, Australia (Carnegie *et al*., 2005). Since the extent of *S. noctilio* infestation is unknown, it is difficult to estimate its annual rate of spread, and the length of time until other areas of the United States are affected by this pest.

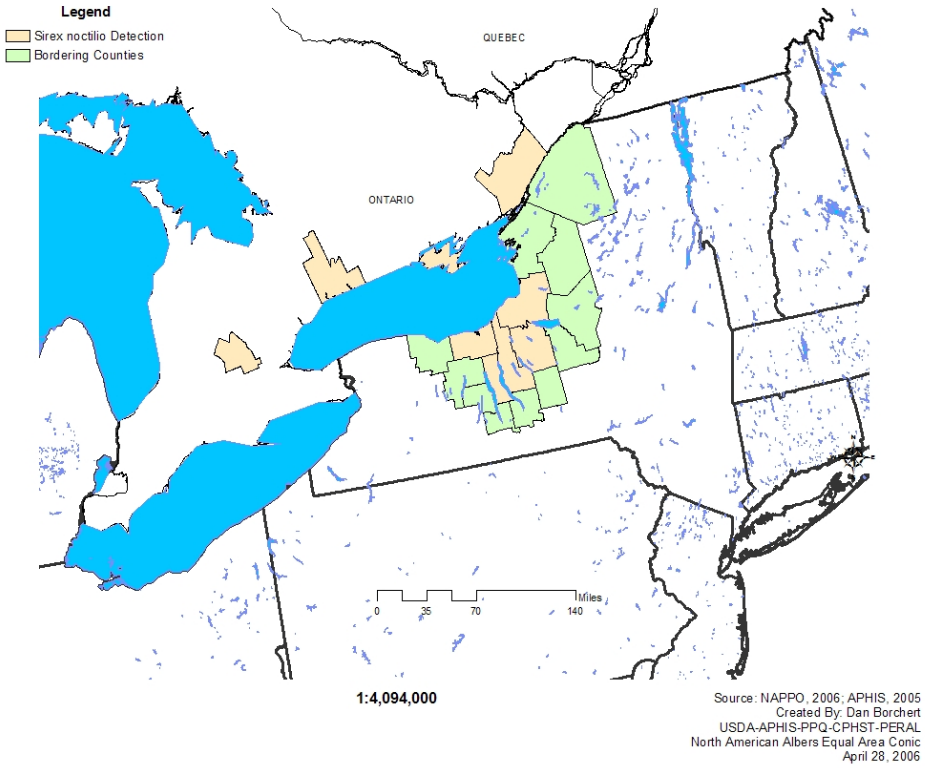

Figure 9. Counties where *S. noctilio* has been Detected and the Bordering Counties in New York State.

Due to the uncertainty of this insect's biology, we utilized two estimates of spread. By using an 18 mile per year spread estimate, we identified the United States and Canadian counties where *S. noctilio* currently resides and the potential portions of Michigan, Ohio, New Hampshire, and Pennsylvania that could be affected within ten years by natural spread (Figure 10).

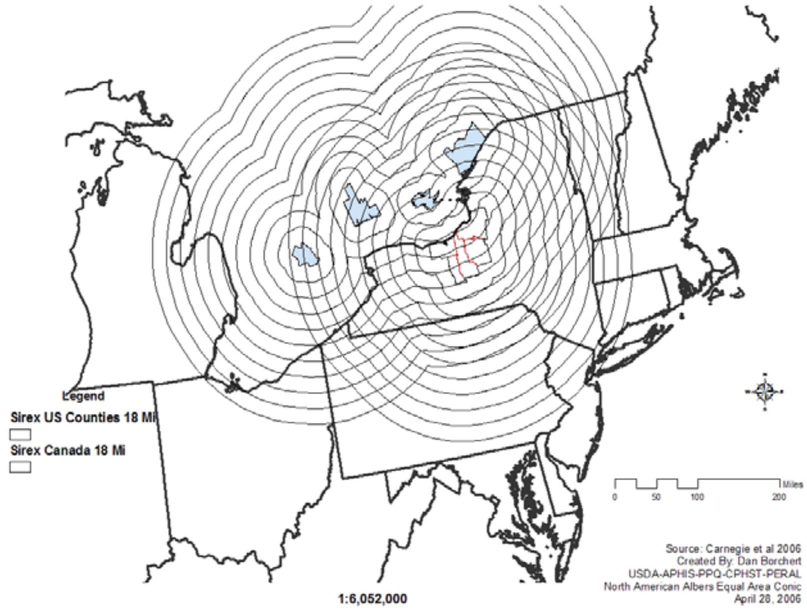

Figure 10. Estimated Spread of *Sirex noctilio* over 10 years. The above figure utilizes an 18 mile/year spread rate in the United States and Canadian counties currently reporting detection.

By using a 25 mile/year spread estimate and the counties in the United States and Canada where *S. noctilio* are currently present, large portions of Michigan and Ohio could potentially be affected by *S. noctilio* within 10 years by natural spread, as well as areas of Maine, Pennsylvania, Indiana, Virginia and West Virginia (Figure 11).

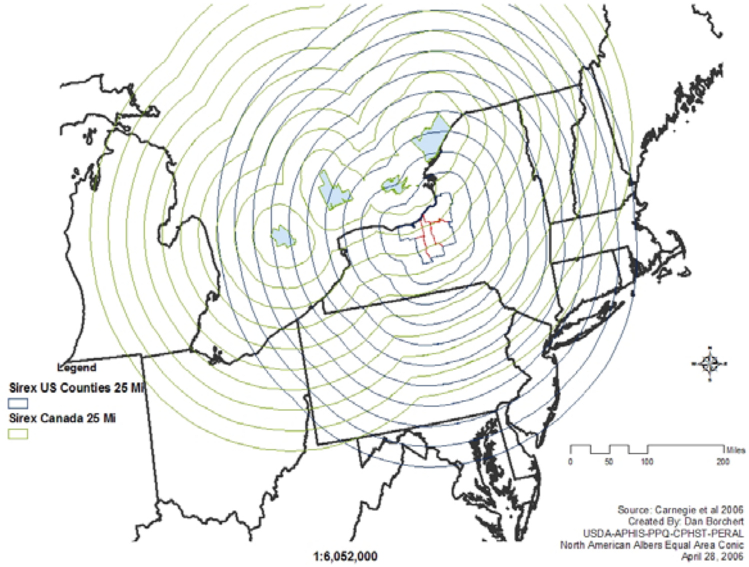

Figure 11. Estimated Spread of *Sirex noctilio* over 10 years. The above figure utilizes a 25 mile/year spread rate in the United States and Canadian counties currently reporting detection.

5.2 Artificial Spread

The following pine articles were considered at-risk for artificially spreading *S. noctilio* by USDA-APHIS-PPQ standards, which include all host materials, living, dead, cut, or fallen, including nursery stock; untreated round wood (logs); untreated sawn wood and untreated wood packaging; firewood; wood chips; stumps; Christmas trees; roots; and branches and debris.

Nursery Stock

Annual sales of coniferous evergreens for 2003 were valued at $443 million, according to a USDA 17 state nursery survey (Table 2) (USDA-NASS, 2004). Several major production nurseries produce and distribute this stock.

Pine trees sold at garden centers and retail nurseries may have passed through several businesses before reaching the retail center. Some nurseries grow planting stock that is sold to other nurseries. Planting stock of pines is commonly sold in the range of 1 to 3 inches to 2 to 3 feet to other growers. These nurseries grow the trees to a larger size either in containers or in the field. Christmas tree growers also purchase a large amount of pine seedlings. Two to three year old pine seedlings are commonly used for Christmas tree production (Koelling and Dornbush, 1992).

The majority of pine nursery stock over 36 inches in height is sold balled and burlapped, with a smaller percent sold in containers (Cinnamon, pers. comm., 2005). Wholesale growers in Ohio grow 5 to 7 feet balled and burlapped Austrian pine for distribution to retail garden centers, re-wholesalers, and landscaping companies (Storts, pers. comm., 2005). The number of trees per acre varies from 1,100 to 1,200. In Ohio, 5 to 7 feet tall pine trees are dug in the early spring during the months of February, March, and April, and then again in the fall from late September through October (Storts, pers. comm., 2005). The majority of trees are dug to order, and then placed on trucks and shipped within two days (Storts, pers. comm., 2005). Insecticides are only applied in the presence of pests; the trees are not sprayed on a routine calendar spray schedule (Storts, pers. comm., 2005). Trees from this wholesale nursery are shipped within a 14 state radius.

Sirex noctilio females prefer trees under stress. In nurseries, it is likely that trees will be well-managed, healthy and not under stress conditions; therefore, it is unlikely that pine trees in nurseries will attact *S. noctilio*, since healthy trees are more resistant to an *S. noctilio* attack (Coutts and Dolezal, 1965). Additionally, if a *S. noctilio* attack is successful, trees will be culled from nursery stock due to the presence of visual symptoms like needle browning and droop, which occurs within a few months of attack. Trees that exhibit these symptoms are unmarketable, and will not likely be shipped. Although *S. noctilio* attacks trees as small as one inch in diameter, it is much more common for trees larger than three inches to be attacked (Morgan and Stewart, 1966). Large pine nursery stock, either in pots, or balled and burlapped, that are over four inches in diameter at the base, will usually ship in the fall, and will not show the characteristic of browning and droop prior to shipment, if infestation by *S. noctilio* has just occurred. The risk for artificial spread of *S. noctilio* through the movement of large nursery stock in the fall is greater than the risk of moving large nursery stock in the spring, as there are no visible symptoms of attack during the fall shipping season The risk of artificial spread of *S. noctilio* through the movement of pine nursery stock from the areas of detection, and the bordering counties where no detection occurred, is M**edium** for large nursery stock during the fall, and **Low** for all pine nursery stock shipped during the spring.

Untreated Pine Roundwood (Logs)

In the 2004 New York Industrial Timber report (Crawford, 2005), the total estimated log production for all hardwoods and softwoods combined was 811 million board feet (MMbf), with 115 MMbf white pine (*P. strobis*) harvested and 45 MMbf red pine (*Pinus resinosa*) (Crawford, 2006). The majority (64 percent) of the timber harvested in New York remains in the state. Exported timber primarily ships to Canada (73 percent), Vermont and Pennsylvania (27 percent), with minor volumes of unreported logs going to multiple New England, Mid-Atlantic and Mid-West states. Of the exported softwood log timber harvested in New York, 96.1 MMbf was exported to Canada, and 12 MMbf was exported to Vermont and Pennsylvania. It is important to note that the New York industrial timber report only addresses logs and pulpwood, and does not address large stock wood products, such as utility poles and timbers used in the log home manufacturing industry.

We considered the potential risk for the movement of immature stages of *S. noctilio* in untreated pine logs to be **High** (Morgan and Stewart, 1966; Haugen *et al.,* 1990; USDA, 1992; Iede *et al.,* 1998). *Sirex noctilio* larvae can survive two or more years in wood, with a relatively low mortality rate if the moisture content of the wood is suitable (above 20 percent oven-dried weight) (Neumann *et al.,* 1987; USDA, 1992). Green pine logs are most attractive and susceptible to oviposition by *S. noctilio* 5 to 7 days after felling, with their attractiveness lasting up to three to four weeks (Taylor, 1981). The movement of infested material to uninfested areas without prior treatment is greatly discouraged (Iede *et al.,* 1998). The level of infestation by *S. noctilio* in the counties where detection has occurred and the effectiveness of visual inspection for log infestation and similar products are unknown. The risk associated with large stock wood products, such as untreated pine utility poles and logs or timbers used in log home manufacturing in untreated form, would be analogous to untreated logs. *Sirex noctilio* could survive within these stock wood products for extended periods of time and the effectiveness of visual detection on logs and poles is believed to be low, however visual detection in timbers and other wood products is probably higher (Crawford, 2006). Because of these characteristics, the risk of artificial spread of *S. noctilio* through the movement of these products from areas where detection has occurred and bordering counties to areas where no detection has occurred is **High**.

Untreated Sawn Wood (Green Pine Lumber) and Untreated Packing Material (Green Pine Packing Material)

Sirex noctilio larvae can survive in sawn and air dried wood and larval presence is difficult to detect if the lumber is rough cut (Fisher, 1955). Chandler (1959) reported other siricidae species emerging from non-kiln dried lumber inside buildings for up to three years after construction. In logs, the eggs and young larvae are susceptible to desiccation, if the wood is too dry. *Sirex noctilio* is not reported to lay eggs in very dry wood, but mature larvae can survive in wood with low moisture content (< 20 percent ODW) (Coutts and Dolezal, 1965). Adult *S. noctilio* emerging from very dry logs in insectaries are very small (Coutts and Dolezal, 1965), and the number of eggs per female are directly related to size (Newman *et al.*, 1987). Siricidae larvae can be moved in wood materials, *e.g.* dunnage, solid wood packing materials, and have been intercepted at U.S. ports-of-entry 149 times since 1985 (PIN, 2005). Of the 149 siricidae intercepted, 17 were identified as species of *S. noctilio*, while the remaining could not be identified below the family level.

Green pine lumber is typically utilized on a local basis, usually within a 50 mile radius of the mill, due to the lower value and limited utility of the product (Crawford, pers. comm. 2006). Solid wood packing material (SWPM) used for domestic applications will be untreated green wood. McIntosh Box and Pallet Co. Inc. headquartered in East Syracuse, New York is a manufacturer of pallets and crating products with four of their five plants located in counties where *S. noctilio* has been detected or in bordering counties. McIntosh uses an estimated nine million board feet of wood per year, with 40 to 50 percent of the wood being softwood. Of the softwood utilized, more than 90 percent is imported from Canada as kiln dried “downfall” product, which is lumber that did not meet the qualifying grade for construction lumber. Kiln drying is a method utilized to kill pests, such as *S. noctilio,* in the wood (APHIS, 2005a). The remaining softwood material comes from New York and Pennsylvania, predominantly as kiln dried downfall product. The use of downfall products is a widespread practice among the SWPM industry in New York. McIntosh reported using untreated green white pine lumber in the manufacturing of a very small amount of specialty products (Huftalen, Pers. communication, 2006).

Due to the limited movement of green pine lumber, and the small amount of green pine material used in the manufacturing of SWPM from the counties where *S. noctilio* has been detected and the bordering counties in New York, we considered the potential risk for artificial spread of *S. noctilio* in untreated sawn wood (green pine lumber) and untreated packing material (green pine packing material) to be **Low**. If the area of *S. noctilio* infestation increases to include areas where untreated packing material utilizes greater amounts of untreated pine host material in the manufacturing of SWPM, the potential risk for the movement of *S. noctilio* by SWPM would increase proportionally, and the potential risk would be **High**.

Firewood (Fuelwood)
As indicated in the previous section, *S. noctilio* can survive and develop within wood for extended periods of time, it is difficult to detect larvae within the wood and it is possible to transport larvae if the material is moved from infested areas. Although there have been no specific papers discussing *S. noctilio* in firewood, the fact that it is able to survive in many other types of semi-dried wood products indicate it would be able to survive in firewood.

According to the 2002 FIA database, there is no indication of any pine being utilized as fuelwood in New York. The only fuelwood listed in New York was from hardwoods, with approximately six million cubic feet of roundwood product growing stock. The FIA collected this data on fuelwood by conducting residential telephone surveys of "individuals or groups of woodland owners who have harvested or allowed fuelwood to be harvested from their land" (Wharton, 2005). The general use and movement of firewood by private individuals on a local basis is probably not captured in the FIA database.

The risk associated with the artificial spread of *Sirex noctilio* through the transport of firewood is **Low** due to the limited production of pine firewood/fuelwood from NY. If the area of *S. noctilio* infestation increases to include areas where pine firewood is utilized in greater amounts, such as Massachusetts, New Hampshire, Maine, Indiana and Michigan (Figure 12), the potential risk for movement of *S. noctilio* by firewood would increase proportionately, and the potential risk would be **High**.

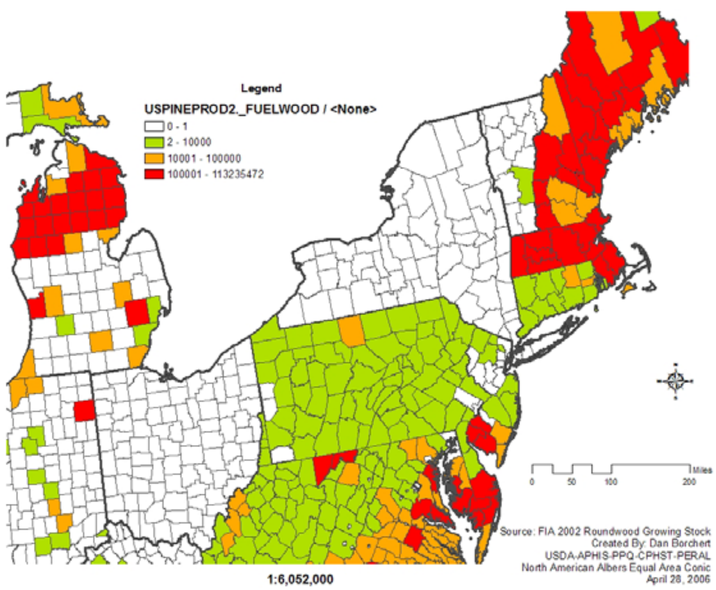

Figure 12. Cubic feet of pine fuelwood product reported by county in the Forest Inventory Analysis (FIA) database. (2002 Roundwood Growing Stock**)**

Wood Chips
The chipping of wood products into pieces 0.625 inch (5/8") (or smaller) at the thickest point helped eliminate all life stages of the Asian Longhorned Beetle (ALB), *Anoplophora glabripennis*, and the Emerald Ash Borer (EAB), *Agrilis planipennis* (APHIS, 2003a; APHIS 2003b). Currently, chipping is an eradication treatment in the ALB and EAB quarantine areas. The larvae of ALB bore deep into the center of logs and are comparable in size to *S. noctilio* larvae. Because of the similarity in habitat and size, the chipping of pine wood products to a thickness of 0.625 inch or less would kill all stages of *S. noctilio*. We considered the risk of artificial spread of *S. noctilio* through the movement of pine wood chips 0.625 inch or less to be **Nil**.

Stumps
Processed stumps can create wood naval stores, which include products such as wood turpentine, wood rosin, dipentene, and natural pine oil (IPPC, 1995). Rosin products can be extracted from chipped stumps or through distillation (IPPC, 1994). Wood rosin is a small component of pine oleoresin production, constituting five percent of production worldwide, or 2,400 tons annually (IPPC, 1995). Wood naval stores production has declined to a low level in the United States in the past 60 years (IPPC, 1995).

Annual sales of rosin products from pine stumps are about 20 million pounds per year (Jacobs pers. comm., 2005). The Hercules Company is the only manufacturer of rosin from stumps in the world. They utilize nine to ten thousand gross tons of stumps per month for production (Jacobs pers. comm., 2005; PINOVA, 2005).

The wood rosin industry in the United States harvests stumps from the coastlines of North Carolina, South Carolina and Georgia (Jacobs pers. comm., 2005). The majority of harvested stumps come from Florida and land 200 miles inland from the Gulf of Mexico in Georgia and Alabama (Jacobs pers. comm., 2005). After timber harvests, stumps from previous harvests are removed. Stumps must be at least 20 years old to produce quality rosin (Jacobs pers. comm., 2005). Harvested year-round, the longleaf and loblolly pine stumps produce naval stores. Because stumps harvested for naval stores are not removed from counties where *S. noctilio* has been detected, we did not consider this as a viable pathway for artificial movement.

In the counties where *S. noctilio* has been detected, and in the bordering counties, the harvesting of pine forest timber does not include the removal of stumps; this is the general practice in New York (Crawford, pers. comm. 2006).

Sirex noctilio will typically infest the stem portion (or bole) of the pine tree with over 90 percent of emergences recorded are from breast height upward to a diameter of three inches at the tree top (Morgan and Stewart, 1966). Green stumps are highly susceptible to attack from *S. noctilio* (Neumann and Minko, 1981). Because pine stumps are not removed from the forests in counties (and bordering counties) from where detection has occurred, *S. noctilio* preferentially attacks the upper stem portion of the tree. We considered the potential risk for artificial movement of *S. noctilio* by the movement of pine stumps to be **Low** to **Nil**. If *S. noctilio* were detected in areas where stumps were removed at the time of log harvest, the risk of artificial spread through the movement of stumps would probably be **Low**, as there may be low numbers of larvae found in the stumps. However, should stumps be utilized for fuelwood, and if processed (chipped) within a short period of time, the risk for artificial spread by stumps would be **Nil**.

Christmas Trees

The estimated proportion of pine Christmas trees sold in New York is 0.16, with an annual value of approximately $1.9 million (Table 1). In New York Christmas tree farms, the estimated majority of newly planted trees are firs and spruce; pines are not as popular with consumers as in the past (Crawford, pers. Communication 2006). Only four of the fourteen tree varieties listed on the Christmas Tree Farmers Association of New York website (2006) were pines.

Sirex noctilio females prefer trees under stress (Neumann *et al.,* 1987). Christmas tree farm trees are healthy, well-managed and thrive under stress-less conditions. Pine trees infested with *S. noctilio* exhibit needle browning and droop within a few months following attack (Haugen *et al.,* 1990; Neumann *et al.,* 1987); these symptoms make the trees unmarketable and reduce the likelihood of shipment. It is unlikely that pine trees in Christmas tree farms will attract *S. noctilio*; healthy trees are able to resist attack (Coutts and Dolezal, 1965), and if an attack is successful, the trees will more than likely be culled during the cutting process. If a tree is attacked by *S. noctilio* in the early Fall, and then harvested prior to signs of attack, it is unlikely that the larvae will be able to complete the 1 to 2 year life-cycle before the tree is disposed of through various collection and recycling methods. Because there is a low proportion of pine Christmas trees produced in New York, a low likelihood of attack on well-managed, healthy trees, a low chance of survival of undetected larvae, and a rapid decline in the marketability of a tree following successful *S. noctilio* attack, we considered the potential risk for artificial spread of *S. noctilio* through the movement of pine Christmas trees from the areas where detection has occurred (and the bordering counties) to areas where no detection has occurred to be **Low**.

Roots

Sirex noctilio prefers to attack the bole of the pine tree, with over 90 percent of emergence reported from breast height and up to three inches in diameter at the tree top (Morgan and Stewart, 1966). The eggs and larvae infest the sapwood layer before moving deeper into the tree (Madden, 1988). There are no reports of *S. noctilio* larvae infesting the roots of pine trees. The roots of pine trees, like stumps, are not removed from the forests at the time of timber harvest. Consequently, we considered the potential risk for artificial spread of *S. noctilio* through the movement of pine roots from the areas where detection has occurred (and the bordering counties) to areas where no detection has occurred, to be **Nil**.

Branches and Debris

Sirex noctilio can emerge from pine branches, as small as one inch in diameter, on standing trees near the trunk. Low numbers are able to complete development in small diameter material, with *S. noctilio* development and emergence occurring when the diameter of the infested pine logs is three inches or greater (Morgan and Stewart, 1966). Larger green pine branches and logging residue are attractive and susceptible to ovipositing females (Neumann and Minko, 1981). Green pine logs are most attractive and susceptible to oviposition by *S. noctilio* 5 to 7 days after felling, with attractiveness lasting up to four weeks (Taylor, 1981). It is a common practice to leave the branches in the forest when pine trees are harvested in New York. These branches, in some instances, may be chipped on site for the utilization in power generating facilities (Crawford, pers. comm. 2006). Due to the low movement of pine branches and logging debris from forests, the reduced ability of *S. noctilio* to develop within smaller diameter material, and the potential risk for artificial spread of *S. noctilio* through the movement of pine branches from the areas where detection has occurred (and the bordering counties) to areas where no detection has occurred, we considered the artificial spread of *S. noctilio* through the movement of branches and debris to be **Nil.** If *S. noctilio* is detected in areas where pine branches and other logging debris are removed from the forest, there could be a **Low** potential risk for artificial spread through the movement of pine branches larger than one inch in diameter**.**

VI. Control Options

Eradication

In Pittwater, Tasmania (1952), an infestation of *S. noctilio* was discovered; however, attempts to eradicate this pest were unsuccessful (Taylor, 1981). The discovery of the pest in Victoria, Australia (1961) initiated the establishment of the National *Sirex* Fund and program in 1962. The program involved an extensive "search and destroy" effort against *S. noctilio*, in addition to multidisciplinary research into management of the pest (Taylor, 1981). The ability of *S. noctilio* to establish and maintain low population levels in moribund branches supported the belief that it would be difficult to eradicate it as a pest (Morgan and Stewart, 1966). The report of the *Sirex noctilio* Science Advisory Panel supported the conclusion that eradication was not a feasible option (APHIS, 2006b).

Chemical Control

The use of insecticides against the adult stage of *S. noctilio* is not feasible because of the adult's short life span the adult's tendency to not feed (making a contact insecticide necessary), the lack of known effective compounds; and the potential impacts on non-target organisms.

Cultural Control

Through good silvicultural practices, the effects of *S. noctilio* can be reduced and more effectively managed (Neumann *et al.*, 1987). Healthy stands that vigorously grow are less susceptible to attack from *S. noctilio* (Haugen *et al.*, 1990). The following recommended measures help to minimize *S. noctilio* outbreaks: 1) timely, selective thinning of forests to reduce overcrowding and tree stress, with increased importance placed on the removal of suppressed, deformed, or multi-stemmed trees and trees dying or diseased; limiting high pruning and non-commercial thinning activities during months when the wasp is active; good site selection, including adequate soil type, soil drainage, and avoidance of steep slopes; and minimizing injury to trees from fire (and other forestry treatments), and the rapid removal of trees damaged by natural events, such as wind, hail, lightning strikes or snow (Neumann *et al.*, 1987). These practices are similar to the management recommendations for the southern pine beetle, *Dendroctonus frontalis*, which promote the thinning of forests from below (to reduce competition) and the removal of high-hazard, damaged or weakened trees (Hyland, 1994).

Biological Control

There are several biological control options available for the management of *S. noctilio*, with the most widespread, well-recognized being the parasitic nematode, *B. siricidicola* (Bedding and Iede, 2005). Currently, *B. siricidicola* is utilized in the management of *S. noctilio* in New Zealand, Australia, South Africa, Brazil, Uruguay, Argentina, and Chile, saving millions of dollars in pine timber (Bedding and Iede, 2005). The biology and use of *B. siricidicola*, which has an insect parasitic stage and a free living mycetophagous stage, has been extensively studied and reported (Bedding, 1968; Bedding, 1972; Bedding and Akhurst, 1974; Akhurst, 1975; Bedding and Iede, 2005). The successful development and refinement of methods for mass rearing, long term storage and inoculation of *B. siricidicola* through the years are encouraging for management of *S. noctilio* (Bedding and Iede, 2005).

Seven North American species of wasps in the family Ibaliidae, which are parasitic on Siricidae, have been identified; two of these species are *Ibalia anceps* and *I. leucospoides* found in the eastern United States (Smith and Schiff, 2002). In Australia, the rearing and release of several different parasitoids for *S. noctilio* management has been conducted, with varying effectiveness (Neumann and Minko, 1981). *Ibalia leucospoides*, reported to occur in New York (Smith and Schiff, 2002), has a life-cycle in near synchrony with its host, rapidly disperses long distances; it is the most effective parasitoid in Victoria (Neumann and Minko, 1981). The parasitic wasps, *Megarhyssa nortoni, Rhyssa hoferi,* and *Schlettererius cinctipes,* have also been recommended for release as biological control agents in Australia to manage *S. noctilio*; these species have been found on other species of *Sirex* in North America as well (USDA, 1992). Additional parasites of Siricids native to the United States include *Rhyssa howdenorum, R. lineolata,* and *R. alaskensis* (USDA, 1992).

VII. Risk Mitigation Options

To reduce the risk of artificial movement of *S. noctilio*, we recommend the following risk mitigation options:

Quarantine

No movement of untreated pine logs, untreated pine utility poles, untreated pine products used in the manufacturing of log homes, untreated sawn pine lumber, untreated pine firewood, and untreated pine branches and logging debris larger than 1 inch in diameter should be permitted from the counties where *S. noctilio* has been detected and the bordering counties.

Fumigation

For importing Monterey pine, *Pinus radiata*, and logs and lumber from Chile and New Zealand into the United States there is a code of federal regulations, Title 7 Chapter III Part 319.40-5, which outlines the mandatory steps and procedures necessary to allow importation. Logs and any regulated wood packing material to be used with the logs during shipment to the United States must be fumigated in accordance with Section 319.40-7 (f)(1) within 45 days following the date of felling, and prior to the arrival of the logs in the United States.

In the USDA-APHIS-PPQ Treatment Manual, the fumigation treatments listed for use on Siricidae (woodwasps) on wood products, including containers, are treatment schedules T404-b-

1-1, and T404-b-1-2; the regulated wood packing material fumigation treatment is T404-e-1 (APHIS, 2005a).

Heat Treatment – Kiln Sterilization

In the USDA-APHIS-PPQ Treatment Manual, the kiln sterilization heat treatment listed for use on Siricidae (woodwasps) on wood products, including containers, is treatment schedule T404-b-4; the regulated wood packing material heat treatment schedule is T404-e-2 (APHIS, 2005a).

The heat requirement to kill *Sirex* listed in a Pest Risk Assessment on the importation of unprocessed logs and chips of eucalypt from Australia (USDA, 2003) is a core temperature of 65°C for two hours.

Drying wood to moisture content below 20 percent oven-dried weight reduces the ability of *A. areolatum* to survive and grow within the wood, and kills the eggs and young larvae of *S. noctilio* (Coutts and Dolezal, 1965).

Chipping

The chipping of wood products into pieces 0.625 inch (5/8") at the thickest point or smaller eliminates all life stages of the Asian Longhorned Beetle (ALB), *Anoplophora glabripennis*, and the Emerald Ash Borer (EAB), *Agrilus planipennis* (APHIS, 2003a; APHIS, 2003b). Currently, chipping is an eradication treatment in the ALB and EAB quarantine areas.

Chemical Treatment of Immature Stages

Inorganic borate salt is a preservative treatment of wood against decaying fungi and wood destroying insects, such as the wood boring beetles in the families Lyctidae, Anobiidae, and Cerambycidae. Depending on the size of the material, borate salt can be applied through dipping or pressure treatment. Vacuum pressure treatment, followed by kiln drying to a moisture content below 18 percent, is currently being utilized by some log home manufacturers in New York. The combination of the two treatments may be effective in eliminating the immature stages of *S. noctilio* within the wood; however, testing and validation of treatment efficacy needs to be conducted.

Timing of Movement

Due to the limited trap catch and observation data currently available for *S. noctilio* in the United States, implementation of this option is under development. As additional data and information become available on the timing of adult emergence, this option may be utilized.

The movement of untreated pine logs, pine utility poles, and pine products used in the manufacturing of log homes during the periods of the year when adult emergence of *S. noctilio* is not likely to occur (15 October –June 15 in New York (***estimated***), would be possible if all materials are treated or converted into a processed product (30 days) before adult emergence. This is not an option for firewood, as it is not a treated or processed product. Examples of treatment are: fumigation, heat treatment (kiln drying), and chipping. Examples of processed products are: pressure treated wood (pressure treated and chemically impregnated), creosote impregnated lumber, wood impregnated with creosote, and wood impregnated with lubricants

(PPQ 578, 2005). Larvae of *S. noctilio* contained within the wood are killed prior to their emergence as adults by the treatments or processing.

The movement of untreated pine logs, pine utility poles, and large pine branches (especially if felled within 45 days) through counties where detection has occurred (and the bordering counties) during periods when adult *S. noctilio* are active (June 15- October 15 in New York estimated) are prohibited and/or regulated. During this period, materials could be attractive to ovipositing females, which could become attached to the wood, and be moved long distances.

The timing of movement risk mitigation option is similar to the regulations currently used on Pine Shoot Beetle, in which articles can or cannot move without treatment during certain periods of the year in relation to the risk presented by the biology of the pest. If *Sirex noctilio* is detected in other areas of the United States, the timing of movement would have to be adjusted to ensure that movement takes place only when adult emergence is not possible.

VIII. Conclusions

Sirex noctilio, a wood boring pest of pines, is a high risk invasive species with the potential to cause serious economic damage to nearly all regions in the continental United States where pines are grown. *Sirex noctilio* is capable of dispersing long distances, both naturally and through the artificial movement of infested materials, such as logs. Eradication of *S. noctilio* is not feasible; therefore, regulations and management are necessary to slow its movement and prevent the occurrence of outbreaks resulting in the loss of pine timber. Effective management of *S. noctilio* involves an integrated approach: restricting the movement of untreated materials during periods of the year when risk of spread is greatest; monitoring infestation through aerial survey, ground survey and traps trees; good silvicultural practices; and using biological control agents, like *B. siricidicola*, when, and if, it is available.

IX. Recommendations

We recommend that strategies similar to those currently being used for the management of *S. noctilio* in Australia (Haugen *et al.*, 1990) and several other Southern Hemisphere countries, be implemented for the management of *S. noctilio* in the United States. These strategies are necessary to prevent the potentially serious economic damage observed when *S. noctilio* outbreaks occur.

To effectively implement the strategies for management, it is necessary to determine the extent and the current levels of *S. noctilio* infestation in the United States. This can be accomplished through grid trapping and aerial/ground surveys of suspected pine forests. It is necessary to prevent the artificial spread of *S. noctilio* in potentially infested materials through the treatment and regulated movement of materials. We recommend a restriction in the movement of untreated pine logs, including untreated pine utility poles, untreated pine logs and lumber used in the manufacturing of log houses, untreated green pine lumber (SWPM), firewood, and nursery stock larger than four inches in diameter at the base from the counties where *S. noctilio* has been detected (and the bordering counties). These materials are considered to pose the highest risk for the artificial movement of *S. noctilio* based on the current distribution.

To reduce the risk associated with the movement of these materials, we recommend utilizing risk mitigation options, such as fumigation, heat treatment, chipping and timing of the material movement. The promotion of education on effective silvicultural management practices is important in reducing a stand's susceptibility to *S. noctilio.* The overall success of the program for *S. noctilio* management may rely on the ability to utilize the parasitic nematode, *B. siricidicola*, as a biological control agent when, and if, the nematode is approved for release in the United States. In other countries, the use of *B. siricidicola* in the management of *S. noctilio* has dramatically increased the effectiveness of the program. However, it is important to realize that this is an ongoing program, and there is a continual need for monitoring *S. noctilio* populations, rearing re-isolation, and inoculation of the nematode. The goal of the *S. noctilio* management strategy is to prevent the occurrence of population outbreaks, and reduce the rate of its potential to spread.

X. Future Research Needs

10.1 Determine the Effects of Competitive Interactions between *S. noctilio*, Native Bark Beetles, and Native Siricids

Research should be conducted to determine the nature of the interaction between *S. noctilio,* native bark beetles, and native Siricidae species.

Research areas:

- Can *S. noctilio* compete with/displace native species?
- What effect(s) does competition have on *S. noctilio* reproduction, survival and host location?
- Will *S. noctilio* cause minimal forest damage in the United States, as it does in Europe and north Africa?
- Will it become a major forest pest as observed in the Southern Hemisphere?

10.2 Determine the Effects of Native Biological Control Agents on *S. noctilio* in North America

Research should be conducted to determine the ability and effectiveness of native Siricidae parasitoids to locate and utilize *S. noctilio* as a host. The large number of native parasitoids present in the United States may be useful in maintaining low populations of *S. noctilio.*

10.3 Information Needed on the Ability to Visually Detect *S. noctilio* and Periods of Adult Wasp Emergence

The ability to effectively detect *S. noctilio* presence in wood through visual inspection in forests and mills is unknown at this time. Better detection of infested materials early in the production chain would reduce the potential for artificial movement. Increased knowledge regarding the phenological development of *S. noctilio* in the United States would allow for better predictive modeling methods of adult wasp emergence. This information is useful in determining periods of the year when material movement would be possible without the risk of adult emergence.

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